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Art. V.—*The Movements of the Soluble Constituents in fine Alluvial Soil.*

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One of the faults of the chemical analysis of the soil, as carried out by the latest methods, is that it pays far too little attention to the soil as a changeable matrix, and attaches too much importance to analyses made usually from samples of soil taken at one time of the year only, and sometimes only from one, or at most two, layers of the soil. This applies even to those analyses where the water-soluble and acid-soluble constituents are separately distinguished. As to the so-called "complete" soil analyses formerly so common, and still in favour in some quarters, these have about as much value to the agriculturist as the destructive analysis of a pair of boots would have to a shoemaker.

In the soil, the constituents of plant food consist (a) of the water-soluble constituents immediately available for use; (b) of the acid (hydrochloric)-soluble ones, representing plant food, which may become gradually available in one to several years. The rest of the soil may practically be regarded as a mere matrix, whose physical properties are of great importance, but whose chemical properties have little or no immediate concern to the plant. The water soluble constituents are concentrated in the surface-adhesion films of water around the solid particles and air bubbles in the soil, so that prolonged washing is needed to remove them completely. The plant, on the other hand, in case of need, can concentrate the dissolved salts in the process of absorption, although when actively transpiring, it usually absorbs them in more dilute form than they exist in the soil.

In any case, every shower of rain falling on the land must tend to lower the percentage of dissolved matter in the surface layers, and will actually do so if no causes are at work in the opposite direction. When evaporation is going on the reverse takes place, the dilute solutions drawn up by capillarity concentrating at the surface. The purpose of the following research has been to determine how pronounced these movements are during an ordinary season, whether they are shown when the land is growing a crop, how manuring affects them, and whether any changes are also shown in the percentage of acid-soluble constituents, and of humus at different depths throughout the year. For this purpose, Mr. Luffmann was so good as to allow Mr. A. G. Campbell to start a series of experimental plots at the Burnley Gardens. These were selected and made up so as to be as uniform as possible throughout each of the two sets of series, one being composed of a fine alluvial sandy soil, the other a rather fine clay, and both having a subsoil nearly sixteen inches below the surface, as will be seen by reference to the following report by Mr. Campbell:—

The soils selected were:—(I) A leached basalt clay, shallow, overlying a very tough clay subsoil; and (II.) deep sand of alluvial nature, overlying white sandy subsoil, with some clay. By preparing the beds well, the subsoil in the first instance was put about 12 inches below the surface, and in the second 15 inches. The elevated beds remained high and dry all the winter, even in series I., which was on quite flat land. The sandy lot sloped very slightly southward. The plots in each series were each 1 square pole in area (30¼ square yards), and treated as follows, the quantities per acre being given in the table of results. The manures were applied in quantities much above ordinary agricultural practice, although the land was already in good heart, since otherwise the amounts in the soil would be almost imperceptible.

Plot 0	Unmanured	
,, 1	Air-slaked Lime	28lbs.
,, 2	Nitrate of Soda (N = 15.5%)	12oz.
,, 3	Star Phosphate (P = 18%)	2lb. 12.8oz.
,, 4	Gypsum	14lb.
,, 5	Bone Dust (N 2.5, P 21%)	2lb. 12.8oz.
,, 6	Sulphate of Ammonia (N 20)	8oz.
,, 7	Blood Manure	1lb. 6.4.oz.
,, 8	Conc. Superphosphate (P 43)	1lb 6.4oz.
,, 9	Quicklime	28lb.

The two series were ploughed and harrowed on 16th May, 1906, then sown with a mixture of rye and oats sown broadcast, The manure was sprinkled evenly on the surface of each plot, and the harrow run over again; both grain and manure being buried 1 inch to 1½ inches. The last plot, however, quicklime, was not sown till a week later, until the lime had slaked and its alkalinity had been reduced.

Growth.—Germination was very good and quick, the weather being favourable. The growth was good in the sand series especially, and continued without a check during winter, there being no noticeable difference between the manured plots and unmanured lands alongside until late in September, when they mostly shot ahead. However, in the clay series, the contrast between raised beds and unformed lands was very great all along, and though growth slackened in very cold weather, it never went yellow like unmanured parts. Representative soil samples were taken about 20th of each month in each plot (a) of surface soil, (b) 8 inches deep, and (c) 16 inches deep. The samples from each plot were bulked to the amount of 1 kilogram of air-dried soil from each depth, which was used for the extraction of food salts. The sixth set of monthly samples was taken in December, three months after the fifth. The crop was harvested green late in October, and gave the following returns:—

Plot	Clay	Sand	Per acre
0	129lb.	120lb.	Unmanured
1	156lb.	140lb.	2 tons Slaked Lime
2	144lb.	139lb.	120lb. Nitrate Soda
3	154lb.	122lb.	4cwt. Star Phosphate
4	121lb.	104lb.	1 ton Gypsum
5	147lb.	121lb.	4cwt. Bone Dust
6	132lb.	132lb.	80lb. Sulphate Amm.
7	136lb.	138lb.	2cwt. Blood Manure
8	143lb.	141lb.	2cwt. Superphosphate
9	72lb.	149lb.	2 tons Quicklime

The injurious action of the quicklime on the crop from plot 9 (clay) was partly due to the seed being sown before the alkalinity was fully neutralised, partly to the binding action of the quicklime on the clay soil. Owing to the fact that the soils were not at all impoverished, the effect of the manuring is not as pronounced as it might otherwise have been, but on the sandy soil the quicklime produced a heavier crop than any other manure, probably because of its solvent chemical action on the mineral constituents of the soil. The superphosphate, slaked lime, nitrate of soda and blood manure seemed to be equivalent as regards the sandy soil, but the two former were more efficient in the clay soil. The star phosphate and bone-dust exercised a strong action on the clay soil, but none on the sandy soil, while the gypsum reduced the yield on both. The order of value for the manures, in the proportions given, are as follows:— For the sandy soil—(1) Quicklime; (2) superphosphate, slaked lime, nitrate of soda, blood manure; (3) ammonium sulphate; (4) star phosphate, bone dust, and no manure; (5) gypsum; For the clay soil—(1) Slaked lime, star prosphate; (2) bone dust, nitrate of soda, superphosphate; (3) blood manure, sulphate of ammonia; (4) unmanured and gypsum; (5) quicklime.

In such cases as these no analyses of the soil, of the crop, or of the manure would enable the results of the application of the latter to be predicted, hence it is essential that the farmer should be guided by local tests rather than by general principles, which are often misleading if improperly applied. Herein lies one of the chief justifications for the existence of experimental plots on farming land throughout the State, and one of the reasons for the avoidance of too much centralisation of experimental field-work in one locality.

A point of great interest is to compare the above data with the fluctuations in the soluble water, and of the humus in the soil. The soil samples were taken from the surface and from depths of 8 and 16 inches, weighed, dried, weighed again, and soaked in 2 litres of distilled water per kilogram of soil. In the first experiments, the clear filtered liquid was boiled down to a small bulk at Burnley, and sent to the University for final testing. The escape of the dissolved carbon dioxide, and the concentration caused, however, a considerable loss, so that all the soil samples were sent to the University, there extracted and filtered. One-half of the liquid added to the soil was evaporated in the same vessel in which the residues were weighed. The total number of soil samples exceeded 400, and the weight nearly half a ton.

Some idea as to the prevailing conditions in regard to moisture and temperature is presented by the following data, giving the percentage of water and the temperatures at different depths during the median portion of the year. From September onwards the temperature became higher, and the percentage of soil water decreased, especially in the upper layers of the soil. Both soils were wettest in July, driest in December.

PERCENTAGE OF WATER.

Date	Clay Soil			Fine Sandy Soil		
	Top	8in.	16in.	Top	8in.	16in.
May 18	18.2	17.5	17.2	11.85	11.85	8.85
June 20	7.75	12.2	11.1	6.5	7.75	8.6
July 20	44.5	42.5	44.5	51.0	54.0	55.5
Aug. 25	24.25	25.25	23.5	17.5	16.5	12.5
Sept. 25	19.0	20.5	22.5	14.0	17.0	19.5

TEMPERATURE (FAHR.) OF EACH IN SITU.

	Clay Soil			Fine Sandy Soil		
	Top	8in.	16in.	Top	8in.	16in.
June 20	50 deg.	49.5 deg.	47 deg.	51 deg.	50 deg.	51 deg.
July 20	46 ,,	45 ,,	45 ,,	41 ,,	43 ,,	43 ,,
Aug. 25	50 ,,	49.5 ,,	51 ,,	51 ,,	50 ,,	51 ,,
Sept. 25	66 ,,	61 ,,	60 ,,	65 ,,	60 ,,	56 ,,

Great difficulty was found in obtaining clear watery filtrates from the clay soil without filtering through biscuit porcelain, which is tedious with large bulks, and is apt to cause the loss of some of the materials really held, originally, in solution. The acid extracts filter readily, but this part of the work was confined to the sandy soils, since the residues from the watery extracts of the clay soil are not at all reliable.

The following are two sets of data from the clay soils in May and September, i.e., before and after the main rainfall, the numbers giving the amount of matter dissolved by 2 litres of water from 1 kilogram of dry soil, plus the amount of non-settling suspended matter able to pass through doubled filter-paper:

	Top		8in.		16in.	
	May 5.	Sept. 25.	May 5.	Sept. 25.	May 5.	Sept. 25.
Plot 0	0.99	0.72	0.88	0.69	0.76	0.98
,, 1	0.76	0.61	0.45	1.16	0.49	1.11
,, 2	0.56	1.12	1.11	1.23	1.25	1.21
,, 3	1 28	1.24	1.31	1.13	1.28	1.15
,, 4	0.81	0.92	1.32	1.38	1.41	1.18
,, 5	0.72	0.64	0.85	1.14	1.25	1.28
,, 6	1.25	1.28	1.11	0.72	1.37	1.38
,, 7	1.2	0.72	1.21	1.28	1.28	1.12
,, 8	1.15	1.28	1.16	0.76	0.96	0.92
,, 9	0.89	0.52	1.13	1.18	1.19	0.81
Average	0.96	0.90	1.05	1.07	1.12	1.11

The data are of value simply as showing the coagulating action of slaked and quicklime, and to a less extent of bone dust and gypsum upon the surface layers of clay soil, while all the other manures appear to have either the opposite effect or only a temporary coagulating action. There is, however, no apparent relation between this action and the crop yield. In addition the surface average falls distinctly after the winter rains.

The sandy soil proved to be more amenable to treatment, and samples were taken from the plots, not only while the crop was growing, but also in December, a month after it had been harvested. The first sets of samples were taken practically simultaneously with the planting of the crop, and shortly after manuring. The manures were applied in the same quantity and order as in the clay plots. The sandy soil was of such density that one acre 1 foot deep would weigh approximately 4,800,000 lb., so that 18 inches deep would weigh 7,200,000 lb., and 2 inches deep, 800,000 lb. In the following table the amount of manure applied per acre is given in the first column, in the second column is the amount per kilogram in the superficial 2 inches, as when first applied, and in the third column the amount per kilogram when spread through the superficial 16 inches, assuming that none had been washed lower down.

		Manure	Amount per acre	Amount in superficial 2 inches. Grms. per Kilogram.	In Upper 16 inches
Plot 1	-	Slaked Lime	2 tons	5.6	0.70
,, 2	-	Nitrate of Soda	120lb.	0.148	0.016
,, 3	-	Star Phosphate	4cwt.	0.56	0.07
,, 4	-	Gypsum	1 ton	2.8	0.35
,, 5	-	Bone Dust	4cwt.	0.56	0.07
,, 6	-	Ammonium Sulphate	80lb.	0.1	0.012
,, 7	-	Blood Manure	2cwt.	0.28	0.035
,, 8	-	Superphosphate	2cwt.	0.28	0.035
,, 9	-	Quicklime	2 tons	5.6	0.7

Although the manures were, on the whole, applied in more than the customary concentrations, the usual application of star phosphate being, for instance, $\frac{1}{2}$ cwt. per acre, it is evident that by the time the manures are distributed through the upper 18 inches of soil the amounts per kilogram will be too small to perceptibly affect the amount of the water-soluble, and still less of the acid-soluble residues per kilogram. Fluctuations in these of less than 0.02 to 0.01 of a gram appear to be meaningless, or, at least, to result from fluctuations or conditions beyond control, such as slight differences in the drainage, in the fineness of the soil, and in the slight unevenness in the distribution of the vital, physical and meterological conditions which affect it during the period of observation. Even when first applied, and distributed at a depth of 2 inches, the nitrate of soda and ammonium sulphate are barely present in sufficient amount to appreciably affect the soluble extractions from the soil by the method of partial lixiviation (2 litres of water to 1 kilogram) employed. By this method is determined merely the amount of soluble material immediately available for absorption, and which can be readily washed from the soil by rain. The blood manure and superphosphate might be expected to produce a distinct temporary rise of concentration in the superficial layers, whereas the relative insolubility of the star phosphate and bone dust would prevent them from producing any direct effect upon the superficial concentration. In the case of plots 2, 3, 5 and 6, any rise of concentration is either the result of a secondary action of the manure on the soil, or to the ascent and concentration by evaporation of the dissolved matter from the deeper layers of the soil. An apparent decrease of concentration may represent either an actual loss or a lessened solubility of certain constituents.

The following table gives the amounts of soluble matter extracted from a kilogram of dry soil by two litres of water, as calculated by the evaporation of one litre of the clear filtrate, the samples of soil taken in May, September, and December of 1906 being tested, and those of intermediate months used for control. The manuring took place in the month previous to the taking of the first samples (and the planting of the crop), while the last set of soil samples were taken the month after harvesting:—

		May 18	Sept. 25	Dec. 20
Plot 0—Unmanured	Top	0.31	0.18	0.49
	8 inches	0.48	0.35	0.48
	16 inches	0.48	0.68	0.41
	Average	0.42	0 40	0.46

The effect of the heavy rains of July, August, and partly of September, in washing the soluble constituents downwards is well shown, and the upward flow of the soluble constituents and their accumulation at the surface is well shown in the December result. The increased average probably partly results from the attraction of soluble matter from still deeper layers, and partly from nitrification in the soil during warm dry weather, after the removal of the crop and the absence of rain allowed the nitrates to accumulate.

		May 18	Sept. 25	Dec. 20
Plot 1.—Air-slaked Lime	Surface	0.53	0.41	0.48
(Two tons per acre)	8 inches	0.32	0.40	0.40
	16 inches	0.12	0.48	0.52
	Average	0.32	0.43	0.47

This plot was obviously poorer originally than the unmanured one, the high value for the top layer on May 18 being directly due to the addition of lime. This appears to keep the soluble matter more uniformly distributed in the upper layers of the soil, and also to cause a greater increase in the December average than occurs in the unmanured plot. The September average also shows a strong increase, in spite of the presence of a growing crop.

		May 18	Sept. 25	Dec. 20
Plot 9.—Quicklime	Surface	0.94	0.64	0.4
(Two tons per acre)	8 inches	0.42	0.5	0.4
	16 inches	0.36	0.4	0.46
	Average	0.57	0.51	0.42

The chemical action of the quicklime results in a liberation of soluble constituents (potash, etc.) in the superficial layers, but so much of this is ultimately washed away that the December average is below that for the preceding plots. The soluble matter is, however, kept evenly distributed, as in the case of the previous limed plots. The use of powdered quicklime for direct application to the soil is coming into vogue in English agriculture, a Birmingham firm manufacturing large quantities of a phosphatic and magnesian powdered lime for agricultural purposes. The lime needs to be drilled in as though it were so much seed, some time before the crop is planted, and its purpose is obviously to render a large amount of soluble matter immediately available for the use of young seedings. It is evident, however, that the quicklime will be apt to exercise an exhausting action on the fertility of the soil, especially in regions with a high rainfall.

Quicklime is often stated to have a special power of burning out humus from the soil, especially if applied at the rate of one or more tons per acre. This is quite incorrect as regards the ordinary mode of application of lime in Agriculture. Quicklime from the kilns, if directly put into the soil, would be rather injurious than useful, since all lumps of any size would retain their causticity in the soil long enough to delay seeding, and by their local action would result in very patchy cultivation. In ordinary practice, to secure fine subdivision and even distribution, lump lime must be allowed to slake in heaps on the surface, which, when the lime has crumbled down, can be scattered and harrowed in. During this process the whole or the greater part of the lime is converted into carbonate of calcium by the carbon dioxide of the air and soil. The presence of a carbonate of an alkaline base or alkaline earth is one of the conditions for the continuance of the nitrification of humus in the soil, the nitrous and nitric acids produced displacing the carbon dioxide from the carbonates in the soil. In this way the accumulation of acid, which is fatal to further nitrification, is prevented, but it must be remembered that strong alkalies like quicklime are very nearly as injurious to the nitrifying and other soil bacteria as are free mineral acids. Hence we should expect to find that the direct application of quicklime would, for a time at least, result in a lessened bacterial oxidation of the humus in the soil, as is in fact shown by the following results, giving the percentages of humus by weight in the dried soil of the various plots at three depths, at the beginning and close of the experiments:—

PERCENTAGES OF HUMUS (fine sandy soil).

		May 5	Sept. 17	Dec. 20
Plot 0—Unmanured	Surface	1.6	1.85	1.8
	8 inches	1.6	1.7	1.75
	16 inches	1.4	1.41	1.3
	Average	1.53	1.65	1.62
Plot 1—Air-slaked Lime (Two tons per acre)	Surface	1.55	—	1.55
	8 inches	1.15	—	0.9
	16 inches	1.3	—	0.65
	Average	1.33	—	1.03

Plot 9—Quicklime (Two tons per acre)	Surface	2.0	—	2.4
	8 inches	1.35	—	1.75
	16 inches	1.5	—	1.45
	Average	1.62	—	1.87
Plots 2, 3, 5, 7, 8 (Bulked Average)	Surface	1.8	—	1.85
	8 inches	1.9	—	1.8
	16 inches	1.9	—	1.8
	Average	1.87	—	1.82

In all the plots, the fallen *dejecta membra* of the crop tend to raise the percentage of humus in the surface layers. The air-slaked lime produced a pronounced fall in the percentage of humus, which, however, increased at a depth of 8 inches with the quicklime, and to a slight extent also in the unmanured plots. At 18 inches, the humus decreased in all cases, though only to a slight extent, except where air-slaked lime was applied. It must be remembered that the quicklime plot produced the heaviest crop, so that the increase in the percentage of humus is, to a slight extent, due to the greater development of the root system, and not entirely to the lessened oxidation. The air-slaked lime produced less crop, and caused a great waste of humus. The averages for the other manured plots show that, as compared with the unmanured plot, the rate of oxidation of the humus was increased disproportionately to its heightened production by the manured crop.

WATER-SOLUBLE CONSTITUENTS (continued).

		May 18	Sept. 25	Dec. 20
Plot 4—Gypsum (One ton per acre)	Surface	1.12	0.36	0.54
	8 inches	0.73	0.72	0.72
	16 inches	0.59	1.11	0.91
	Average	0.81	0.73	0.72

The gypsum is comparatively readily soluble, and comes readily away in the filtrate. It is easily washed downwards by rain, a very large part being lost during the rainy season, but is drawn to a certain extent up to the surface again in dry weather. The manurial value of this substance is commonly greatly exaggerated. It has but little of the favourable mechanical action of lime, it does not favour nitrification, and is a poor and expensive way of adding calcium to the soil. The unduly high manurial value attached to it may possibly arise from the fact that, when plants are grown in nutrient solutions, the calcium is often for convenience supplied in the form of the sulphate, which is more soluble than the carbonate, not poisonous like the chloride, and less liable to contamination with injurious impurities than the nitrate. Gypsum exercises, however, a feeble action in freeing potash in soils containing this substance in an insoluble form, but it is much less active than quicklime. It also neutralises alkaline soil or alkaline irrigation water. Thus—

Neutral soluble gypsum		Alkaline soluble sodium carbonate		Neutral air-slaked lime		Soluble neutral sodium sulphate
$CaSO_4$	and	Na_2CO_3	form	$CaCO_3$	and	Na_2SO_4

No action of this kind took place, however, in the soil under examination, and in both the clay and sandy soils the gypsum reduced the yield below that for the unmanured plot. Gypsum is, in fact, a substance which has crept into agricultural use as a manure largely under false pretences. Even its action on manure heaps in preventing the loss of ammonia is largely exaggerated, and the same end is far better and more cheaply attained by packing the manure tightly in walled enclosures or in pits shielded from the weather.

		May 18	Sept. 25	Dec. 20
Plot 2—Nitrate of Soda	Surface	0.48	0.29	0.40
(120lb. per acre)	8 inches	0.32	0.37	0.41
	16 inches	0.32	0.58	0.40
	Average	0.37	0.41	0.40
Plot 6—Sulph. of Ammonia	Surface	0.43	0.405	0.34
(80lb. per acre)	8 inches	0.53	0.49	0.44
	16 inches	0.55	0.41	0.36
	Average	0.5	0.435	0.38

Both these manures are highly soluble, and since they represent in the case of the nitrate of soda 0.148 gram per kilogram of the superficial 2 inches, and in the case of the ammonium sulphate 0.1 gram per kilogram, it is evident that the movements of the added salts are not solely responsible for the results, which are partly due to an indirect action, or to the absorptive action of the crop. The latter probably explains the steady decrease in plot VI., which appears to be less affected by rain than usual, and to show no increase in the superficial layer after drought. The plot II. shows the usual movements of the soluble matter, though these are not very pronounced, and the slight increase in the average shows that the solvent actions in the soil more than balanced the loss by drainage and by the crop.

		May 18	Sept. 25	Dec. 20
Plot 3—Star Phosphate	Surface	0.59	0.37	0.36
(4cwt. per acre)	8 inches	0.34	0.53	0.44
	16 inches	0.48	0.42	0.44
	Average	0.47	0.43	0.41

The manure being only sparingly soluble, the steady decrease of the averages probably represents soil constituents previously present. These show the usual drop after rain in the surface layer, and no absolute, but only a relative increase or lessened decrease on the surface after dry weather.

		May 18	Sept. 25	Dec. 20
Plot 5—Bone Dust	Surface	0.51	0.32	0.44
(4cwt. per acre)	8 inches	0.50	0.43	0.41
	16 inches	0.63	0.52	0.38
	Average	0.55	0.42	0.41

This resembles the preceding closely, except that the concentration on the surface in December is better shown. Both cases indicate an exhaustion of the soluble soil constituents by the crop or by drainage, for if the manures fixed or precipitated the soluble constituents, the first surface estimation in May would be a low instead of a high one.

		May 18	Sept. 25	Dec. 20
Plot 8—Calcium Superphosphate	Surface	0.54	0.36	0.46
(2cwt. per acre)	8 inches	0.57	0.51	0.40
	16 inches	0.56	0.52	0.44
	Average	0.55	0.46	0.43

Although the manure is highly soluble, and the amount of it not too small (0.28 gram per kilogram of upper 2 inches when first applied), it does not seem to produce any pronounced direct effect upon the changes in the distribution of the soluble matter in the soil, which resemble those in the preceding plot.

		May 18	Sept. 25	Dec. 20
Plot 7—Blood Manure	Surface	0.64	0.61	0.42
(2cwt. per acre)	8 inches	0.67	0.6	0.41
	16 inches	0.55	0.56	0.54
	Average	0.62	0.59	0.46

The blood manure apparently exercises an important indirect action on the soil, increasing the amount of soluble matter present in it. The action apparently continues for some time, and suffices to maintain a high percentage in the surface soil of September, in spite of the previous rains. Even in December the average is higher than in any of the three preceding plots. Presumably the blood-manure sets up active nitrification in the soil, and this involves a considerable conversion of difficultly soluble or insoluble earthy and alkaline bases into readily soluble nitrates. One part by weight of the nitrogen of the blood-manure is capable of producing 6 parts of calcium nitrate, or 10½ parts of potassium nitrate. The effect on the crop was similar to that of the nitrate of soda on plot II.

If stock owners would abandon the practice common in certain parts of allowing dead stock to rot in creeks by running water, or to decay where they fall, and instead to bury all dead animals so that they are covered by at least a foot of soil, the nitrogen and phosphates of the carcase will enrich the soil, instead of being wasted, and the land-owner will benefit instead of the streams being polluted, or the land disfigured. The benefits of burying do not merely consist in the saving of nitrogen for the soil, but also apply to the phosphates of the bones which become much sooner available for plant use when the carcase is buried than when the bones left on the surface to bleach and weather quite hard. Bare bones when buried rot slowly, especially in calcareous soil, but if surrounded by flesh their disintegration is hastened. Hence the carcase should be buried while still fresh for practical, as well as for æsthetical, reasons.

Changes in the Acid-Soluble Constituents.—For complete comparison, a knowledge of the changes in the acid-soluble constituents of the soil is necessary, for these are in a continual process of solution, absorption, and reprecipitation, and undergo an increase during the slow disintegration of the soil, as well as being liable to decreases of chemical or physical origin (precipitation, formation of double or dehydrated salts, allotropic changes, etc.). The use of drastic solvent agencies is inadvisable, since these could quite readily give a false impression as to the condition of the soil. Hence for the extraction, 2 litres of very dilute hydrochloric acid of approximately decinormal strength were added to each kilogram of dry soil. One litre of the clear filtered liquid was evaporated to dryness, and the weight of residue doubled. The values obtained may be taken as giving the amount of mineral matter in the soil capable for the most part of solution and absorption under exhaustive conditions in from one to several years.

The acid extracts filtered readily and came through quite clear with a single filtering. This is mainly the result of the coagulating action of the acid, which, by lowering the surface tension of the finely divided particles, causes them to coalesce and then settle rapidly. To a slight extent it is due to the solution of some of the finer particles, for on adding acid to a turbid watery filtrate it cleared to a slight extent by solution, the remaining suspended particles then settling. Throughout the following tables the numbers in brackets give the acid soluble less the water-soluble matter.

		May 5	Sept. 25	Dec. 20
Plot 7—Blood Manure	Surface	5.08 (4.44)	4.25 (3.64)	3.68 (3.26)
(2cwt. per acre)	8 inches	5.74 (5.07)	4.41 (3.81)	3.96 (3.55)
	16 inches	5.64 (5.09)	5.4 (4.84)	3.76 (3.22)
	Average	5.49 (4.87)	4.69 (4.1)	3.8 (3.34)

If these figures are reliable, they indicate that blood manure causes a liberation and loss of the reserve plant-food which is altogether out of proportion to the amount removed by the crop. By itself, therefore, blood manure should seem to have a very exhausting action on the soil, and there is no evidence to show that the materials rendered soluble are drawn up to the surface again to any appreciable extent from the deeper layers of the soil. Instead, being mainly nitrates, they readily wash out of it and are lost.

		May 18	Sept. 25	Dec. 20
Plot 2—Nitrate of Soda	Surface	5.02 (4.54)	4.58 (4.29)	5.68 (5.28)
(120lb. per acre)	8 inches	4.72 (4.38)	4.50 (4.13)	4.1 (3.69)
	16 inches	4.8 (4.48)	5.02 (4.44)	3.68 (3.28)
	Average	4.84 (4.50)	4.70 (4.29)	4.48 (4.08)

The fluctuations at different depths might possibly be the result of imperfect sampling, which is always of great importance, however homogeneous the soil may appear to be. The averages, however, show a steady decrease. It is always possible that soluble material from one layer may continually diffuse towards another layer in which it is deposited by some kind of chemical precipitation, or as a result of evaporation, or the loss of a solvent gas. This may be the case here, although the fluctuations in the percentage of acid-soluble and water-soluble matter show no apparent relationship. The latter represents, however, merely the condition at the time of taking, whereas the former results from cumulative action prior to sampling.

		May 18	Sept. 25	Dec. 30
Plot 6—Ammonium sulphate	Surface	6.55(6.12)	5.64(5.24)	6.16(5.82)
(80lb. per acre)	8 inches	6.34(5.81)	5.7 (5.21)	5.7 (5.34)
	16 inches	6.25(5.7)	6.32(5.91)	4.8 (4.56)
	Average	6.38(5.88)	5.89(5.45)	5.55(5.24)

Here the acid-soluble matter undergoes on the average a distinctly greater reduction than in the previous plot, in spite of its lesser yield of crop. The variations closely follow those in plot II., so that it appears as though acid-soluble matter passes downwards to some extent after prolonged rain, and is slowly drawn upwards during prolonged drought.

		May 18	Sept. 25	Dec. 30
Plot 8—Star Phosphate	Surface	5.36 (4.77)	5.06 (4.69)	4.36 (4.0)
(4cwt. per acre)	8 inches	4.98 (4.64)	4.76 (4.23)	4.8 (4.36)
	16 inches	5.40 (4.92)	5.18 (4.76)	4.72 (4.28)
	Average	5.25 (4.78)	5.0 (4.56)	4.63 (4.21)

		May 18	Sept. 25	Dec. 30
Plot 5—Bone Dust	Surface	5.3 (4.79)	5.2 (4.68)	5.7 (4.26)
(4cwt. per acre)	8 inches	4.92 (4.35)	4.86 (4.43)	4.58 (3.87)
	16 inches	4.96 (4.33)	4.82 (4.3)	4.04 (3.66)
	Average	5.06 (4.36)	4.96 (4.47)	4.67 (3.93)

In plots III. and V. the amounts of manure added represent 0.56 gram per kilogram of the surface 2 inches, and 0.07 per 18 inches depth. Since only a portion of each is soluble in the the dilute acid used, it is evident that the steady fall represents mainly materials previously present in the soil. In the star phosphate plot no superficial accumulation of acid-soluble materials takes place in December, but this phenomenon is shown with the bone dust plot, possibly because of secondary reactions excited by the organic material of the bone dust.

		May 18	Sept. 25	Dec. 30
Plot 8.—Calcium Superphosph.	Surface	6.08(5.24)	5.61(5.25)	4.1(3.62)
(2cwt. per acre)	8 inches	7.96(7.39)	7.2 (6.69)	4.4(4.0)
	16 inches	5.86(4.66)	5.22(4.5)	4.2(3.74)
	Average	6.63(5.76)	6.01(5.58)	4.2(3.79)

The amount of manure added represents 0.28 gram per kilogram of the superficial 2 inches, and the high solubility explains the high amount of water-soluble matter in the superficial layers on May 18. At the same time the superphosphate seems to exercise a strong solvent action on the soil itself, of such character as to strongly increase the amount of matter soluble in dilute acid. The net result is to leave the soil distinctly poorer in matter soluble in dilute acid than any of the previous plots, but if this matter is utilised by the crop it represents an increased yield and profit instead of so much inert material. Unfortunately but little appeared in the crop as ash, so that superphosphates by themselves appear to be highly wasteful and exhausting. If these facts hold good for soils in general, the exclusive use of phosphates in Victorian agriculture is likely to rapidly exhaust the fertility of the soil, not only because of the greater demands of the increased crop, but also because the superphosphate exercises a secondary action on the soil, temporarily increasing the amount of water-soluble matter and also that of materials soluble in very dilute acid. The former are rapidly and the latter slowly removed from the soil by the action of rain water charged with carbon dioxide as well as by the crop.

		May 18	Sept. 25	Dec. 20
Plot 4—Gypsum	Surface	5.2 (4.08)	4.04 (3.68)	4.2 (3.66)
(One ton per acre)	8 inches	4.4 (3.67)	3.9 (3.18)	3.5 (2.78)
	16 inches	4.15 (3.56)	3.4 (2.29)	3.1 (2.19)
	Average	4.58 (3.77)	3.78 (3.05)	3.6 (2.88)

		May 18	Sept. 25	Dec. 20
Plot 0—No Manure	Surface	3.32 (3.01)	3.9 (3.72)	4.58 (4.09)
	8 inches	3.90 (3.42)	3.4 (3.05)	3.44 (2.96)
	16 inches	3.82 (3.34)	3.7 (3.02)	3.06 (2.65)
	Average	3.68 (3.26)	3.7 (3.26)	3.69 (3.23)

Not only did the gypsum produce a less crop yield than the unmanured plot and unduly increase the amount of water-soluble material liable to waste by drainage, but it also caused a pronounced decrease in the amount of acid-soluble material by the end of the year. In the unmanured plot the averages remain very nearly constant in spite of an increase towards the surface and a decrease in the deeper layers.

		May 18	Sept. 25	Dec. 20
Plot 1—Air-slaked Lime	Surface	6.3 (5.77)	5.08 (4.67)	5.44 (4.96)
(Two tons per acre)	8 inches	4.6 (4.18)	4.68 (4.28)	5.12 (4.72)
	16 inches	4.88 (4.76)	4.46 (3.98)	4.0 (4.48)
	Average	5.23 (4.9)	4.74 (4.31)	4.85 (4.72)
Plot 9—Quicklime	Surface	7.38 (5.44)	7.66 (7.02)	7.08 (6.68)
(Two tons per acre)	8 inches	6.34 (5.92)	6.7 (6.2)	5.52 (5.12)
	16 inches	6.38 (6.02)	6.5 (6.1)	5.6 (5.54)
	Average	6.7 (6.13)	6.95 (6.44)	6.07 (5.78)

The acid-soluble materials appear to increase in the quicklime plot in September, and are throughout high. This is undoubtedly due to the chemical action of the quicklime on the soil, and this action involves a considerable waste of food materials by the end of the year. This waste is not apparent in the case of the slaked lime plot, in which, as in the unmanured plot, the total amount of readily soluble material appears to be greater in December than it is after the winter rains in September. In all the other plots the amount steadily decreases towards the close of the year.

For convenience of reference a joint table is given beneath showing the averages from the upper 18 inches for all the plots in parallel columns. From the totals it appears that the manure added represents the ash of the crop fourfold, and that the total apparent loss from the soil was four times greater than the amount of chemical manure added. In other words, chemical manures do not permanently enrich, but rapidly impoverish, fine soils poor in humus, especially when applied in excess.

SUMMARY.

As regards the unmanured plot, the sodium nitrate appears to lower the percentage of dissolved matter during the eight months following its application; the slaked lime lowers the amount at first, but by the end of the year it is up to the normal level again. In all other cases, the amount of water-soluble matter is increased at first, and lowered below the unmanured level by the end of the year, except in the case of the gypsum, in which it remains high in spite of a heavy loss, and of the blood manure, in which it does not fall below the amount in the unmanured plot.

In regard to the distribution of the soluble matter in the different layers, the downward movement, as the result of continuous rain, and the less marked upward ascent during drought, were well shown by the unmanured, slaked lime, gypsum, nitrate of soda, bone dust, and superphosphate plots, while the downward movement was merely lessened in summer, and not actually reversed in the case of the quicklime, ammonium sulphate, star phosphate, and blood manure plots. The averages for the water-soluble matter in all the plots are remarkably consistent with the conclusions mentioned, the surface showing a fall and rise, 8 inches depth a slow fall, and the 16 inches an almost similar rise by the end of the year.

AVERAGE WATER-SOLUBLE MATTER FOR ALL THE PLOTS.

	May 18	Sept. 25	Dec. 20
Top	0.61	0.39	0.43
8 inches	0.49	0.48	0.45
16 inches	0.46	0.47	0.49

The amount of matter soluble in dilute acid underwent a secondary rise at the end of the year in the superficial layers in the case of the unmanured, sodium nitrate, ammonium sulphate, bone dust, and slaked lime plots, but in all other cases decreased steadily in the surface layers of soil. The quicklime plot was exceptional in showing not only a rise in the superficial layer in September, but also an increase in the average for the whole 16 inches, followed by a pronounced fall in December. As regards the averages, these decreased during the year in all the plots excepting the unmanured and slaked lime plots, but the increases in these were very slight in amount.

AVERAGE MATTER SOLUBLE IN DILUTE ACID FROM ALL THE PLOTS.

	May 18	Sept. 25	Dec. 20
Surface	4.82	4.69	4.56
8 inches	4.88	4.52	4.04
16 inches	4.69	4.41	3.76

The average acid-soluble matter decreases steadily on the surface and more rapidly in the deeper layers, especially during the summer months.

Without claiming anything more than a preliminary and suggestive value for these data, they nevertheless may be taken to apply to the fine alluvial soil occurring on so many river flats and valleys in Victoria. None of the manures as applied in the somewhat excessive quantities given would have paid for their application by the increased crop yield. It will further be noticed that the apparent loss from all the plots excepting the slaked lime and unmanured ones (where there is a slight gain) is very much greater than can be explained by the ash removed by the crop. To what extent these apparent losses are real ones, and to what extent they are due to decreases in solubility, to increases in absorptive power, or to changes in distribution, must be reserved for further investigation. As far as they go they seem to show that the fine alluvial. sandy river-flat soils widely cultivated in many parts of Victoria appear to be peculiarly liable to exhaustion under the action of all chemical manures excepting slaked lime. Even if the maximal apparent loss (85lb.) were entirely a real loss, it would take 530 years to remove the top 16 inches, assuming that all was removed by solution and none by erosion. These soils appear also to be comparatively deficient in humus, but where this is not so the manurial diagnosis in the case of virgin soil would be slaked lime at the rate of ½ to 1 ton per acre, until the soil begins to show signs of exhaustion, then farmyard manure at a probable minimum of 2 to 5 tons per acre, soluble, nitrogenous, or phosphatic manures to be used sparingly, or not at all unless the soil shows need for them.

PRACTICAL AXIOMS.

Quicklime binds a clay soil, slaked lime ameliorates it.

Quicklime in excess exercises a wasteful solvent action on composite sandy soils. Small quantities drilled in prior to seeding should, however, stimulate the early growth of seedlings, and perhaps lessen the danger of infection by fungi.

The indirect action of a manure on the soil is usually much more important than its direct chemical value as a nutrient substance. This applies not only to those manures which exert a direct chemical action on the soil, but also to those nitrogen-containing, acid or alkaline manures which affect the activity of the micro-organisms in the soil.

Chemical manures, especially soluble phosphatic ones, should not be applied in any quantity to soils poor in humus, except in company with farmyard manure or some form of humus.

The soil is a changeable matrix, whose percentage solubility in water and acid varies appreciably at different depths throughout the year, and also undergoes seasonal changes as a whole, especially under the action of chemical manures. The apparent losses from the soil after heavy manuring are many times greater than the ash contained in the crop, and also greater than the amount added to the soil by any of the chemical manures used excepting lime.

The oxidation and nitrification of humus in the soil is more favoured by air-slaked lime than by the direct application of quicklime, so long as the latter retains any alkalinity injurious to nitrifying micro-organisms.

Postscript.

Since the above was written, Mr. Hall has drawn my attention to the fact that Norman Taylor, in MacIvor's "Chemistry of Agriculture," 1879, p. 224, suggested that the superficial limestone deposits common in the Mallee may have been produced by the continued drawing up of chalk in solution by capillary action from the moister layers below. This explanation was adopted by Howchin for the desert limestones around Adelaide, and was extended by Gregory ("Geography of Victoria," 1903, p. 93) to the hard siliceous superficial cherts or quartzite beds, and also to the ironstones of superficial gold deposits. Recent research has, however, shown that iron bacteria may play a most important part in the formation of iron deposits wherever water is present, and such deposits will, in the first instance, be superficial. In any case, the data obtained by me are insufficient to do more than establish the fact that material may rise to the surface in dry weather, but say nothing as to whether wet weather may not wash it down again to an equally great extent. The alkaline ash left after bush fires would certainly tend to carry silica downwards again as soon as any rain fell.

Plot.	Manure per acre	Grams per Kilog. per 2 inches depth	Grams per Kilog. per 16 inches depth	Crop yield in lbs. per sq. pole	Max. calculated crop ash in lbs. per sq. pole	Water-soluble matter 1 Kilog. in 2 litres			Decrease or increase	Matter soluble in acid only, 1 Kilog. in 2 litres, N/10 HCl			Decrease or increase	Total apparent decrease or increase per sq. pole of 16ins. depth, in lbs.	Manure added per sq. pole
						May 18	Sept. 25	Dec. 20		May 18	Sept. 25	Dec. 20			
0	No Manure - - -	—	—	120	1.6	0.42	0.40	0.46	+0.04	3.26	3.26	3.23	−0.03	+0.45	Nil.
1	Slaked Lime (2 tons) -	5.6	0.7	140	1.87	0.32	0.43	0.47	+0.15	4.9	4.31	4.72	−0.18	+1.35	28lbs.
2	Sod. Nitrate (120lbs.) -	0.148	0.016	139	1.85	0.37	0.41	0.40	+0.03	4.50	4.29	4.08	−0.42	−17.5	12oz.
3	Star Phosphate (4cwt.)	0.56	0.07	122	1.65	0.47	0.43	0.41	−0.06	4.78	4.56	4.21	−0.57	−28.3	2lb. 12.8oz.
4	Gypsum (1 ton) - -	2.8	0.35	104	1.39	0.81	0.73	0.72	−0.09	3.77	3.05	2.88	−0.89	−44.1	14lbs.
5	Bone Dust (4cwt.) -	0.56	0.07	121	1.61	0.55	0.42	0.41	−0.14	4.36	4.47	3.93	−0.43	−25.6	2lb. 12.8oz
6	Amm. Sulphate (80lb.)	0.1	0.012	132	1.76	0.5	0.435	0.38	−0.12	5.88	5.45	5.24	−0.64	−34.2	8oz.
7	Blood Manure (2cwt.) -	0.28	0.035	138	1.84	0.62	0.59	0.46	−0.16	4.87	4.1	3.34	−1.53	−76.0	1lb. 6.4oz.
8	Calcium Superphosphate (2cwt.)	0.28	0.035	141	1.88	0.55	0.46	0.43	−0.12	5.76	5.58	3.79	−1.79	−85.9	1lb. 6.4oz.
9	Quicklime (2 tons) -	5.6	0.7	149	1.99	0.57	0.51	0.42	−0.15	6.13	6.44	5.78	−0.35	−22.5	28lbs.
	Totals -	15.93	1.99	1296	17.44	5.18	4.81	4.56	−0.62	48.21	45.51	41.20	−6.83	333.3	79lb. 10.4oz.